§4. Effect of Constituents on Thermal and Electrical Conductivity of SiC/SiC Composites

Hinoki, T., Park, Y., Lee, Y. (Institute of Advanced Energy, Kyoto Univ.),
Tanaka, T., Muroga, T.

Silicon carbide fiber reinforced silicon carbide matrix (SiC/SiC) composites are considered as functional-structural materials for advanced energy systems, because of their excellent thermal, mechanical and chemical stability, and the exceptionally low radioactivity following neutron irradiation. In particular, flow channel inserts (FCIs) made of SiC/SiC composites were proposed as a means for thermal-electrical insulation between the flowing liquid metal and the load-carrying channel walls to reduce the MHD pressure drop in the dual-coolant lead lithium blanket channels of fusion reactors.[1)]

In this collaborative study, electrical and thermal conductivities of the monolithic sintered SiC materials of Hexoloy-SA and NITE-SiC (Nano-Infiltration and Transient Eutectic-phase: NITE) have been examined to obtain fundamental data required for tailoring of performances of SiC/SiC composites. Increases in the electrical conductivities under a radiation environment, i.e. radiation induced conductivities (RICs), have also been examined under Co-60 gamma-ray irradiation.[2)] SiC/SiC composites consist of three constituents: SiC fiber, SiC matrix and Carbon interface layer. In the present study, electrical and thermal conductivities of the SiC/SiC composites have been examined focusing on their dependencies of SiC fiber orientations.

Electrical and thermal conductivities have been examined for SiC/SiC composites fabricated in Kyoto University. The materials consisted of NITE-SiC matrix, SiC fibers of 7 μm in diameter and Carbon interface layer. Two types of specimens were prepared by changing array directions of the SiC fibers in SiC/SiC composites, such as uni-directionally oriented SiC fiber (UD specimen) and 2-dimensional oriented SiC fiber (2D specimen) as shown in Fig. 1. The SiC fibers volume fraction was approximately 40 %. Electrical measurements were performed for the parallel and perpendicular directions to the SiC fibers as shown in Fig. 2. Gold electrodes with the diameter of 2mm were painted on the both sides of the specimens and connected to a current source and electrometer. The electrical conductivities were evaluated by correcting the influence of the electric field distribution in the specimen according to results of FEM calculations. Thermal conductivities were also measured by the laser flash method for the parallel and perpendicular directions. The laser flash method relies on the generation of a thermal pulse on one face of a thin sample and the recording of the temperature history on its opposite face. The thermal diffusivity can be determined from the time required to reach one-half of the peak temperature in the temperature rise curve on the rear surface.

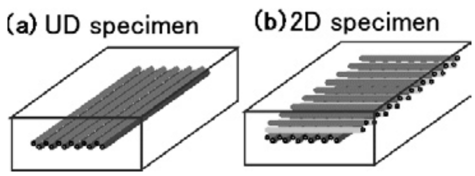

Fig. 1 Two types of SiC/SiC composites with difference array directions of SiC fibers

Current-voltage (I-V) curves showed ohmic characteristics in both the UD and 2D specimens. The electrical conductivities of the UD specimen were 1.6 x 10^2 S/m in the perpendicular direction to the SiC fibers and >3.7 x 10^3 S/m in the parallel direction. Those of the 2D specimens were 5.1 x 10^2 S/m and >3.6 x 10^3 S/m, respectively. In the measurements for the parallel direction, the maximum measurable electrical conductivities were limited by contact resistances at the electrodes. Results of thermal conductivity measurements for the UD specimen were 66 W/mK in the perpendicular direction and 69 W/mk in the parallel direction. Those for the 2D specimen were 67 W/mK and 62 W/mK, respectively. While the difference larger than one order appeared in the electrical conductivities depending on the measurement direction, thermal conductivities were almost the same magnitudes for both the measurement directions. It is considered that the SiC matrix dominates the thermal conductivity in the SiC/SiC composites. On the other hand, the anisotropic results in the electrical measurements imply that the electrical conductivities were affected by the carbon interfacial layers between the SiC matrix and fibers. Detailed analyses of the constituents are required in the future study.

1) Tillack, M. et al.: Proceedings of the 17^{th} IEEE/NPSS Symposium Fusion Engineering (1997) 1000.
2) Hinoki, T. et al.: 2009 NIFS annual report p.221.

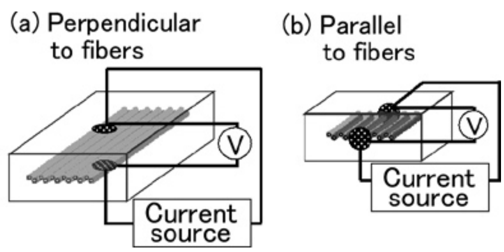

Fig. 2 Schematic drawing of electrical measurement for SiC/SiC composites.